

## User experience and learning experience in a 4D virtual reality simulation game

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### Abstract

*Simulation training is an effective way of teaching in healthcare, yet it requires a great deal of time and effort. Virtual gear technology brings us new promising training methods, yet there is very little research data about the user experience and learning in immersive virtual environments. This research was based on the idea that 4D virtual reality simulation games can supplement traditional simulation training and provide consistent training to a wide group of professionals. As learning should be effective, it should also be pleasant enough to motivate professionals for continuous training. Therefore, user experience was emphasized in this study and learning effectiveness was not measured. This study explored the gaming and learning experience, as well as usability, in a multi-phase scenario based on the evidence-based theory of resuscitation. The participants played the scenario and were interviewed immediately afterwards. Their experiences of the 4D virtual simulation game were explored in the context of educational games and general theories of UX. Material from 13 thematic interviews was analyzed by applying a deductive content analysis. The findings suggest that gaming and learning experiences are very individual and vivid. Immersion created by the virtual gear had an essential impact on the overall experience. In addition, authenticity, interaction and feedback were important elements of learning experience. Usability had a major role on the whole. The findings are discussed in relation to earlier studies and actual practise as well as trustworthiness and challenges of overall implications.*

**Keywords:** *virtual reality, simulation game, 4D, user experience, learning experience*

### 1 Introduction

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The digital transformation has affected numerous fields in our society. In the field of education, it challenges us to re-think our methods and processes and enables new ways of teaching and learning. Constant progress in game technology appears to have a major impact in professional education and learning, and thus it is highly important to explore the subject from different perspectives. In order to get people to adopt new ways of studying and learning, new methods need to feel pleasant and reasonable. This less known subject was approached openly by combining the general theories of usability, user experience (UX) and the multidimensional framework for the evaluation of adaptive educational games, created by Law & Sun [1].

In this study the gaming experience is explored through user experience (UX). As a concept this comprises the usability of the user interface as well as the feelings, expectations

and benefits that the subject brings to its user [2; 3; 4]. At the same time fast advances in digital educational games renders their UX evaluation more challenging [1].

Since there is very little research on serious games with virtual equipment (4D) we approached the subject in the context of educational games and UX. In this study 4D refers to a game with a virtual headset, also called immersive environment, with sounds. Regarding many serious games studies and simulation studies in healthcare, it seems that the terminology on the field is unclear. “3D” may refer to a screen version game and “virtual” as a concept may refer to any kind of simulation of the reality, also simulations with a high-fidelity training manikin. Therefore, it is important to understand the diversity of previous research data and the differences in user interfaces.

The main objectives of this study were to explore the UX of a 4D simulation game for health care professionals and the factors that, according to users, enhanced learning. The research questions were:

1. How was the gaming experienced?
2. How was the usability experienced?
3. How was the learning experienced?

## 2 Background

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In healthcare education most serious games are low-fidelity, video clips of actors portraying patients in a hospital setting [5] or text-based scenarios that have been supplemented with images and/or videos [6]. In addition to that, three-dimensional (3D) virtual worlds have been used and found to bring realism into learning in both nursing and medical education [7; 8; 9]. Recently, efforts have been made to enhance learning by adding game elements into virtual simulations [10; 11]. One study proved that playing a mobile-accessible, case-based, online game improved pregraduate and postgraduate medical learners' knowledge in recognizing and managing sepsis [12]. However, the challenge related to gamified applications in the area of healthcare is that their benefits for clinical outcomes might not meet expectations [13; 14]. Similar challenge relates also on the learning outcomes. It is difficult to evaluate the actual benefits of certain platforms since the face, content, construct, and predictive validity of studies is often poorly assessed [15].

Especially in medicine, simulators and haptic simulators have long been used to develop surgical skills, such as the skills needed in laparoscopic surgery. Haptic simulators recreate the sense of touch and create a more immersive learning experience. Reznek et al. [16] found already in 2002, that haptic simulator CathSim was a valid instrument for teaching intravenous catheterization in medical education. This result was later confirmed when positive learning outcomes were found when intravenous simulators incorporating virtual reality/haptics device technologies were used for practical exercises of intravenous injection [17]. A more recent study showed that virtual laparoscopic skill training for gynecologic surgery had significant learning effect on novice, intermediate and expert gynecologic surgeons [18]. Rosser et al. [19] found a link between video game playing and laparoscopic surgical skills and suturing skills: video game players make fewer mistakes and perform faster than nonplayers.

The use of augmented reality has also become more common and it has been implemented in several areas, such as laparoscopic surgery, administration of local anesthesia, endotracheal intubation, clinical breast examination, and life support training [20]. A study by Rajeswaran et al. [21] revealed that a virtual reality based immersive trainer for endotracheal intubation with a headset and two hand controllers increased healthcare professionals understanding of the intubation procedure. They also found that participants knew how to navigate and interact with instruments inside the virtual reality environment. The age of the participants (n = 9) was between 20 and 21. Previously, it has

been argued that the more junior the participants are, the more likely it is that training using virtual reality models will improve their knowledge and skills [15].

Defining the scope of UX and operationalizing experimental qualities is challenging [22], and therefore the theoretical background was constructed from a combination of literature and studies from the field of studies on human-computer interaction. UX is always subjective and different users respect different features, which depend on the needs of the user. The ease of use and overall usability are essential parts of the UX, but also individual opinions concerning the visual appearance play an important role. Motivation and expectations as well as preconceptions are all part of the UX [4; 23].

In the context of adaptive digital educational games UX can be divided into four dimensions, which are: 1) the gaming experience, 2) the learning experience, 4) adaptivity, and 5) usability. These dimensions have specific attributes that influence the UX in context [1].

3D technology has stimulated some debate on the pedagogical aspects of 2D and 3D games and there is still a lack of a clear consensus on the benefits of the latest 3D technology in serious games [24]. When it comes to 4D virtual reality simulation games (hereinafter 4D simulation games), there is even less research data. In healthcare, 4D simulation games are interesting because simulations have long been used and are seen as a useful learning method [25], and 4D technology may bring opportunities to the field.

Simulation training is a common method in healthcare, especially on the acute care. However usually simulation training means a session with a medical high-fidelity manikin, which have features like speech, cough and other sounds. These simulations implemented using a medical manikin noticeably enhance critical thinking, information seeking and recognition of deteriorating patient states [26]. Such simulations, however, require major resources. Simulation games may be an option to partly replace them, or at least bring elements of simulation to a wider audience. Learning methods that reproduce reality allow students and professionals to practice and learn the key competences of their professions [27; 28]. Virtual learning in healthcare is considered an efficient method of education [29] and serious games are an important element in this respect, even though hands-on training can never be totally replaced [30; 31]. Koivisto et al. [10] found that when playing simulation games, usability, the application of theoretical knowledge, and exploration have the most impact on learning. Students have reported that in order to create meaningful learning experiences, simulation games used for educational purposes, should have similar characteristics to entertainment games. These include aspects of visual authenticity, interactive 3D environments, high-quality animation and sound. Also, immediate, sustained, and delayed feedback are important [11].

Healthcare professionals are expected to have the ability to think critically, to prioritize, and to follow treatment protocols. This requires that the learning objectives and game mechanics are integrated in such a way, that the simulation replicates real clinical situations [11]. Authentic patient-related experiences seem to be the most obvious motivating factor in healthcare related simulation games [11]. Authenticity requires realistic and challenging clinical conditions, which are possible to achieve by audio-visual representation using multidimensional digital characters such as virtual patients and interactive medical equipment. Animations, such as the movements, gestures and facial expressions of a patient enhance the authentic experience.

Interactivity is another important aspect of immersion in simulation games. Interactivity refers to the interaction between the learner and the virtual environment, and it enables players to see the consequences of their actions. The more effectively the interaction is enabled, the more realistic and engaging the learning experience will be [11]. VR is more immersive than simulation games played on the screen of a computer or on a pad. Thus, the interaction can be enabled even more effectively.

According to Cook et al. [32] digital games enhance learners' knowledge, psychomotor skills, and decision-making skills. Simulation games can also effectively improve healthcare students' knowledge and skills for practical skills such as cardiopulmonary resuscitation. Life support skills have a significant impact on patient safety and they should

be practised regularly. In life support simulation game scenarios, the learner has to use previous theoretical knowledge in order to deal with the situation [10]. Simulation games seem to be effective tools for gaining and maintaining life support skills. In a comparison between engaging in a game and traditional classes, the gaming group of students achieved significantly better learning acquisition scores and also performed cardiopulmonary resuscitation protocols better [33]. In advanced life support training a 3D digital serious game was proved to be effective in knowledge and skills acquisition as well as in maintaining them at least until the three-month follow-up [34].

### 3 *4D virtual reality simulation game*

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The 4D virtual reality simulation game used in this study was originally developed as a part of Koivisto's PhD study [35]. The game simulates real-life clinical situations and patients' clinical conditions. It consists of patient scenarios, which are events designed around a specific clinical situation requiring clinical reasoning. The game was developed with Unity3D and played on a Samsung Galaxy phone (S6 and upwards) using Samsung Gear VR. In this study, the immediate life support scenario was developed into the simulation game platform. The theoretical background behind the game scenario is based on the newest guidelines of the European Resuscitation Council (ERC). The scenario was created by an experienced nurse and ERC advanced life support instructor and revised by an ERC course director level emergency medicine physician, who is also a member of Finnish Resuscitation Council [36]. The learning goals were to learn how to assess critically ill patients by using the ABCDE approach, to start immediate treatment for acute coronary syndrome (ACS), to know how to perform cardiopulmonary resuscitation and how to start immediate post resuscitation care (Table 1). These learning goals were translated into mechanical elements of gameplay [11; 28; 37; 38] (Table 2). According to Carvalho et al. [38], serious game components include three activities: the gaming activity, the learning activity and the instructional activity. All these activities are further classified according to three layers: actions, tools and goals. In the context of this study, gaming activity refers to action points such as asking questions, reading information and selecting the right option. Learning actions, on the other hand, refers here to analyzing information and applying theoretical knowledge. In this game, the intrinsic instructional activity is built into the game, including tools such as help text, limited set of choices and tips.

The scenario consisted of three parts. In the first part the patient suffers from chest pain and the participant has to evaluate and start treating the patient according to the ABCDE approach and follow the chest pain treatment protocol. The evaluation is made by choosing actions from multiple choice options (Figure 1). Instant feedback on the choices is given in the game either "from the patient" (via speech and gestures) or in a textbox (theoretical background).

**Table 1.** *Implementation of the scenario from the user point of view.*

LEARNING GOAL	ACTIONS	VIRTUAL ENVIRONMENT
To master the <b>ABCDE APPROACH</b>	Multiple choice questions with immediate feedback. Feedback from the patient verbally and with gestures.	Patient room and virtual patient. Monitor on after the right choice. Neutral sounds.
To be able to carry out <b>IMMEDIATE TREATMENT OF ACUTE CORONARY SYNDROME</b>	Multiple choice questions with immediate feedback. Feedback from the patient verbally and with gestures.	Patient room, virtual patient and monitor on. Neutral sounds.
To be able to <b>PERFORM CARDIOPULMONARY RESUSCITATION</b>	Multiple choice. Proceeding to next question only after the right choice.	Alarm sounds. Timing on sight.
To be able to provide <b>IMMEDIATE POST RESUSCITATION CARE</b>	Multiple choice with immediate feedback.	Patient room, virtual patient and monitor on. Neutral sounds.

**Figure 1.** *The actions are chosen from multiple choices.*

Once the first part is completed, the second part starts when the participant has started the essential treatment. The patient collapses and the participant chooses the right actions from a multiple-choice menu according to the resuscitation guidelines. In this part there are factors that may cause stress, such as a running time limit for answering the questions and an alarm sound. After answering the questions, the participant proceeds to the part three.

In the third part, the patient is in the intensive care unit and needs post-resuscitation care. Just like in the first part, the participant needs to select the correct actions and values according to post resuscitation guidelines. Information and feedback are given to all the answers in a text box or displayed as values on the monitor.

**Table 2.** *Examples of learning and game mechanics in the 4D virtual reality simulation game.*

Learning mechanics	Game mechanics	4D virtual reality simulation game
Simulation Participation Experimentation Responsibility	Story Realism Role play Simulate/response	<p>Story: The story of the game is the recognition, monitoring and management of the critically ill patient in the hospital ward.</p> <p>Realism: The game consists of realistic clinical patient scenarios: A 3D patient with authentic reactions in a 3D hospital ward environment with authentic equipment. A patient's clinical condition and any changes can be observed with the help of authentic graphics and animations.</p> <p>Role play: The player actively participates in patient care and acts in the role of a healthcare professional; a first-person view.</p> <p>Simulate/response: The game simulates real life immediate life support situation. The sense of presence is fortified using VR headset, which maps players head movement one-to-one into the 3D world. Using headphones with the VR headset, the 3D spatial sound and the ability to look around by turning head can immerse the player even more into the game. Interaction with the game's user interface is done by either looking at it ("Gaze control") and tapping the VR headsets touch pad or using a wireless controller. The wireless controller detects players hand rotation, so it can be used like a laser pointer. Playing the game with a VR headset puts the players inside the actual 3D room and lets them look around and interact with the 3D objects. This represents real life situation better than the same scenario played through a computer screen.</p>
Observation Identify Plan Action/Task Question & Answer	Strategy/planning Action points Time pressure	<p>Strategy/planning: Game mechanics were built around the clinical reasoning process: collecting and processing information, identifying problems and issues, establishing goals, taking action and evaluating outcomes.</p> <p>Action points: Non-linear gameplay allows the player to move forwards and backwards between interview, assessment and implementation sections based on the patients' clinical condition.</p> <p>Time pressure: fast-paced mode, in which players compete against time and must make quick decisions.</p>
Reflect Analyse Repetition	Feedback Assessment Competition	<p>Feedback: Receiving immediate, sustained, and delayed feedback causes learners to analyse and reflect their decisions and enables them to track their competency development. Immediate feedback includes correcting errors, scoring, patient reactions, in-game facilitator's comments, the effects of success and failure. Sustained feedback includes changes in patients' clinical conditions during gaming, the accumulation of scores, documentation of players' choices in the log. Delayed feedback includes total scores, description of performance.</p> <p>Assessment: scores, stars, final evaluation.</p> <p>Competition: the player competes against oneself and the player group. The performance can be improved by repeating the scenario, which helps players to internalise and automatise procedures so that they could perform them correctly in a real situation.</p>

## 4 Method

### 4.1 Research design

We explored the subject using a qualitative method consisting of a user study with thematic interviews. Individual experiences were essential, so group sessions were not used. The themes of the interviews followed the multidimensional framework for evaluation of adaptive educational games, created by Law & Sun [1] and the last theme applied to game design and improvement.

As usability is seen as an essential feature of UX in educational games and is an important aspect in this study, we evaluated it referring to the five attributes of usability; learnability, efficiency, memorability, errors and satisfaction [39]. The found usability problems were also rated by severity on scale from 0-4 [39].

### 4.2 Data collection

The data was collected in gaming sessions. Participants were recruited from various units of acute care by sending an invitation to participate by email or other group messages. Thirteen health care professionals from the invitees volunteered to participate. The participants were invited to individual sessions. The sample represented the target audience of the game. The participants were nurses ( $n = 7$ ), paramedics ( $n = 3$ ), teachers ( $n = 2$ ) and one emergency physician. The average age was 39 years (SD 7,5). Nine participants had no, two had very little and two had some previous experience of virtual reality. Participants came to the gaming session one at a time, at a time agreed in advance. The gaming sessions were organized outside participants workplace in an office room without interference. All the participants signed the informed consents in the beginning of the sessions.

The instructions and goal (to play the game all the way through) were explained before the participants put the VR gear on. One of the researchers was available all the time throughout the session and the participants were instructed to ask for help with any usability issues that may arise. The researcher helped and instructed the participants during the session. The participants played the scenario through once or twice and were interviewed immediately afterwards. No time limit was specified for the game or the interview.

First the VR gear and the idea of the session were explained to the participant. The participant put the VR gear on and learned how to control the game and the gear (Figure 1). The scenario was initiated by the participants when they felt ready. The gaming sessions took 10-28 minutes.



**Figure 2.** A participant learning how to control the game.

The sessions (the gaming and interviews) were audio recorded. Immediately after the game session, when the user experience was very recent, the participants were interviewed by one of the researchers. The interview was semi-structured, with the aim to obtain descriptive thoughts and opinions of the participants about the UX of the game. The interview consisted of open questions around 6 themes. Gaming experience, learning experience, adaptivity and usability were themes from the theoretical framework of Law & Sun [22]. Usefulness and game development as themes described the overall attitudes and UX in large scale. With the help of the researchers' notes from the game session, the researchers were able to return to usability issues which had arisen during the game sessions. The interviews lasted 14-40 minutes and altogether there was 309 minutes of interview data.

### 4.3 Data analysis

The theoretical framework used for the deductive content analysis [40] in this study was created by Law & Sun [1] for their research on UX in adaptive digital educational games. In this multidimensional framework UX is divided into gaming experience (for example, the challenge, flow, immersion, and so on) and learning experience (for example, the appropriateness of the content, understandability of the goals, quality of the feedback, etc.), game adaptivity (for example, attention and learner responses to instructional stimuli), and general usability (for example, navigation, ease of control, learnability, and responsiveness). In addition to these features of UX, we explored how the participants felt about the usefulness of the game and analyzed how that specific game should be improved according to the participants.

The interviews were transcribed by a professional transcription service company. The data was analyzed in several phases separately by two researchers. The researchers worked independently by categorizing the impressions and sentences to the categories defined in the theoretical framework (i.e. the gaming experience, learning experience, game adaptivity, usability, usefulness and game improvements). After each phase, the categories were compared before the next phase. The researchers went through several phases to organize the data into categories and then to abstract the results from the categories. Quantification was not seen as feasible because the aim of the study was to discover new information from the users. There were no contradictions in the final results of the two researchers and the conclusions were alike.

## 5 Results

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### 5.1 Gaming experience

The participants described the gaming experience vividly, vocalizing their feeling with lively, emotional expressions and through examples. The gaming experience is described through the multidimensional framework by Law & Sun [1]. In this framework the gaming experience is described as the result of a number of attributes, including the challenge, flow, immersion, positive and negative aspects and tension (Table 3). The following paragraphs describe how the participants viewed these attributes.

*The first aspect described here is the challenge.* The content was experienced as challenging, but the learners felt it was mostly appropriately challenging. The degree of challenge in the game was seen as a beneficial attribute and contributed to the subject of the scenario. A 4D simulation game was viewed as an appropriate way to confront the challenging subject in a safe way. All the participants expressed that, due to the "new environment" (the 4D aspects) they needed some time to orientate themselves to the 4D simulation game before they could concentrate on playing the game. This orientation phase

was described as confusing and some participants felt that they did not understand what was expected from them.

Some of the participants stated that they felt the content was complicated. The same participants also felt the scenario as more challenging. However, most of the participants described that after the orientation phase, playing the game was easy. The big picture was seen as appropriate and some participants would have liked to see even more elements in the game. The participants viewed the degree of challenge differently, and in some cases, similar attributes were felt to be positive or negative depending on the participant.

*The second aspect discussed here is the flow of the game.* Usability played a major role in the experience of the game flow. Problems with usability had a negative effect on proceeding in the game. Some participants said they felt that the large amount of content also disturbed the flow, because they did not know what to concentrate on. In general, the participants felt that the flow and advancement in the game was smooth.

*The third aspect discussed here is immersion.* All the participants stated that they felt strongly immersed in the game. According to their descriptions, the game “absorbed” and “engrossed” the players. The participants reported that they lost their sense of time and focused fully on the game. The situation was experienced as authentic and because of the authenticity of the visual environment and the patient, many felt genuinely concerned for the patient. According to the participants the gear also played a major role in the immersion, because there was no option to do anything else but play, once the gear and the game were on. The most of all, the answers in this study, especially the descriptive ones, concerned immersion.

*The fourth aspect discussed here are the positive and negative feelings of the gamers.* In the UX of the game, authenticity had a positive effect; the seemingly authentic patient and environment enabled the participants to make authentic observations. Especially the visuality of the game and patients’ gestures and the real time monitor made the situation very authentic. At the same time it was still experienced as a safe environment for training. Some participants felt the soundscape was good, because real situations are usually noisy, but some participants found the sounds disturbing. Many of the participants felt that the game was a supportive and motivating experience, but some answers revealed that the 4D did not bring the expected enhancement to the gaming experience, because the functionality consisted very much of scrolling and selecting options from menus and in that way it was found to be very similar to screen interface functionality.

*The last aspect discussed here is the tension the learners experienced.* Some participants reported that they felt the tension when they selected the wrong answer. These participants reported that this was more to do with their own nature rather than about the game. Some participants said they felt tense because they could not act as they could in a real situation.

**Table 3.** Attribute, sub-attributes and expressions of the gaming experience.

ATTRIBUTE	SUB-ATTRIBUTE	EXPRESSIONS
Challenge	Challenging content	<i>"It was reasonably challenging, not too difficult, but not too easy either."</i> <i>"I think, if resuscitation is not very clear to someone, it is just that you play more often so that you get it right."</i>
	Influence of virtual environment	<i>"You need to take your time in the beginning to explore the options, so that you learn the game characteristics."</i> <i>"Well, in the beginning, if you haven't used such things, there's the new environment, but otherwise I think it was appropriately simple, there were not too much stimuli."</i>
Flow	Disturbance from the game mechanics	<i>"On the whole, maybe too much for me. Too much all kinds of windows and levels."</i>
	The feeling of proceeding as in real life	<i>"As a player you just want to get further and don't mind about the order."</i> <i>"When you get oriented, then it just pulls you into the flow."</i>
Immersion	Immersion due to equipment	<i>"This is just so intensive and the world outside is blocked."</i> <i>"Because it's capturing, you cannot concentrate on anything else than that."</i>
	Immersion due to content	<i>"It does that, it takes you. It is really good fun to be in that room."</i>
Positive and negative feelings	Explicable opinions	<i>"It's nice, that when you are in that situation, you really see that the patient is not doing well and you immediately notice things, like he's really not breathing well and all that, and then your knowledge and skills activate."</i> <i>"As an environment, it was like in hospital, authentic."</i>
	Emotive positive feelings	<i>"It was a blast."</i>
Tension	Tension due to game mechanics	<i>"Maybe it was because at first it was difficult to realize what I've got to do there, that I got slightly annoyed."</i> <i>"The music, possibly brought some tension. Or pressure."</i>
	Stressful situation	<i>"I didn't feel stressed at all. Maybe it's because I'm such a pro. (laughing)"</i>

## 5.2 Usability

The usability was explored as one attribute of the UX and revealed some important findings. The results were represented by using Nielsen's severity rating scale [39] and include usability issues regarding the game itself but also the scenario (Table 4).

Most of the participants' problems with usability were resolved during the game session with the help of the attending researcher. These problems were discussed in the interview after the game session.

## 5.3 Learning experience

According to the results a good learning experience requires assimilation of the goals, appropriate content and feedback (Table 5). There were many similarities, but also many differences in the answers given by the participants, however on this subject. The described learning experiences suggest that the learning experiences were very individual. The most important individual factors that enhanced learning, according to the participants, were the authenticity of the scenario, interaction and feedback.

*In terms of the goals*, the learning goals were mentioned before starting the game orally by the researcher and shown in writing at the start of the game in the 4D environment. Still, some of the participants felt that they did not exactly understand them. Despite this, these participants felt they learned from the game. Those participants, who felt they understood the goals, reported that they reached the goals fully or at least partially.

**Table 4.** *Perceived usability issues.*

PROBLEM	SEVERITY	EXPLANATION	SUGGESTION
<b>Adjustment difficulties with the perspective. Need to get further away from the objects.</b>	4	The visual perspective was narrow, easily lacking some essential information	Adjusting and controlling the perspective further from the patient should be easier.
<b>Touch screen of the head gear too sensitive.</b>	3	This caused several false clicks.	Hand-held controller in the newer version.
The participant got “lost”.	3	Lacks clear in-sight navigation instructions (back to the patient etc.)	“Help” button should be in sight all the time. Careful placing of the objects to help navigation.
<b>Not enough feedback.</b>	3	The participant did not have a clear picture of what has been done and what is expected to happen next.	Continuous feedback needed in scenarios. An option to take some time out would be good.
<b>Adjustment of sharpness not good enough.</b>	2	Some participants felt this was annoying.	This gets better with new technology but needs to be considered in placing the subjects.
<b>Menus overlap each other.</b>	2	The view was unclear.	The placement of the objects needs consideration, fewer menus, more VR-features (grab and move etc.) needed.

*In terms of content appropriateness*, the participants described the content as beneficial and up-to-date. The opinions about the scope and depth varied considerably. These aspects were described in the more extreme cases as polar opposites, such as “too deep” or “too shallow”. Most of the participants, however, were satisfied with the content in relation to the learning goals. According to the participants, the authenticity of the content was an important factor that enhanced their learning.

*Regarding the feedback*, the game was seen as motivating, but the experiences concerning of the amount of feedback varied a lot. The interviews showed that due to the 4D perspective, many of the participants had missed at least some of the feedback. Therefore, the usability had an unexpected influence on the learning. The content of the feedback was seen as mostly appropriate, but some participants would have wanted more depth. The interaction and feedback were seen as the most important factors enhancing the learning. According to the participants, the motivating tone of the feedback left a positive feeling about the learning experience.

*The game adaptivity* was explored through the participants’ logical progress in the game. The results show that adaptivity is a sum of the structure of the scenario, feedback and usability. Most of the participants felt that the game enabled logical progress at least somehow. The participants were able to use their earlier skills and knowledge mainly well. In the extreme opinions the game was experienced as “walking through the scenario hand in hand” and on the other hand causing so much stress that the participant could not act like he would have done in a real-life situation. The role of feedback was important in the adaptivity and many participants would have liked to have clearer phases and the possibility to move back and forth between the phases. According to the participants, usability issues and going through the different phases of the game scenario had the biggest impact on adaptivity.

**Table 5.** Attributes, sub-attributes and expressions concerning the learning experience.

ATTRIBUTE	SUB-ATTRIBUTE	EXPRESSION
Goals	Requires fast decision making	<i>"I felt it was really good for learning to make decisions and act under pressure." "It's very much problem solving to get to the goal."</i>
	Understanding the goals	<i>"Good knowledge of CPR was a clear goal, but somehow for me the use ABCDEs as a goal was not clear, so I don't think I reached it very well."</i>
	Arouses motivation	<i>"The game really motivated me to update my skills even more"</i>
Content appropriateness	The quality of medical content	<i>"The depth of knowledge was shallow." "Really up-to-date content."</i>
	Content suitable for game	<i>"It is a safe way to practice the subject, without harming a patient. Good way of learning these things."</i>
	Multiplicity of the content	<i>"Very interesting concept. In your mind, thinking of learning, because of the visuality, you see what is done and it kind of enhances processing. You just have to think."</i>
Feedback	Immediate feedback	<i>"I think it was good that you immediately saw why your answer was wrong. The explanation is very important." "Like, when I gave Nitro, I was told to pay attention to the blood pressure. So, you get important knowledge all the time." "And that the monitor was real-time; it showed real information. And also the patient showed how he is."</i>
	Overall amount of feedback	<i>"It didn't give enough feedback."</i>
	Tone of feedback	<i>"I felt it was supportive. It was positive feedback."</i>
Game adaptivity	Guidance through feedback	<i>"The game guided well through; first the interview and you got the patient data. And then the multiple choice guided what you should do and in what order. You didn't have to know, you had choices." "The game walked you through. Too much guidance."</i>
	Feeling of orientation	<i>"There was at some point, like, transition.. like what's happening now."</i>

## 6 Discussion

The aim of this study was to explore gaming experience, usability and learning experience of a 4D simulation game in the field of healthcare, specifically acute care and resuscitation. The results show that the user experience including all three mentioned aspects, was very individual and emotive. Several features of the game were experienced both positively and negatively, depending on the participant. Usability played an unexpectedly important role throughout the experiences. The four dimensions of UX according to Law and Sun [1] proved to be an efficient way to analyze and explore the gaming experience and UX of the 4D simulation game in this study.

*The gaming experience* was immersive and the gaming situation was felt authentic concerning both the patient and the surroundings. According to the participants the virtual gear enhanced concentration compared to other methods of studying. However, the reader should bear in mind that the study did not measure the learning outcome. The findings of this study only describe UX and learning as individual experiences, not through learning results.

The findings suggest that the characteristics of the UX of a 4D simulation game are similar to the general characteristics of UX definitions, in which the UX is described as a multidimensional entity. Participants' varied experiences verify that the gaming experience

is subjective and that users value different things depending on their needs [23]. All the participants envisioned possibilities and a new way of studying with 4D simulation games in the field of healthcare. Some participants were very critical about different aspects of the game. However, all the participants would be ready to maintain their skills and expertise at least partly by using a game. Despite the criticism, the value and benefits of 4D simulation games were seen as a larger beneficial phenomenon. In retrospect, this conclusion may also tell about the participants' positive attitudes towards new technology as well as today's challenges in the acute care skills and education. Nevertheless, the findings support the assumption, that virtual gear and serious games are welcome to the field of healthcare training.

*Usability* was a major issue in this study, but on the other hand, it is fairly simple to explore and develop once the problems are stated. In this study the participants' experiences of usability were somewhat alike. Many of the encountered usability problems seemed to exist due to the lack of experience in games and scenario development and therefore were fairly easy to fix. These findings gave valuable information about the different requirements of on-screen and 4D virtual gear interfaces. According to this study, the usability plays a unique role, because unlike the other dimensions, it has an impact on all the other dimensions as well.

The effects of the features of the virtual gear interface and the objectives of the game have to be considered carefully when assessing the usability. In this study the biggest challenge in terms of usability was the limited view, which did not enable the users to take a step back to see the "bigger picture" in a critical situation. Taking a step back is an essential gesture in simulations and real life situations, hence this particular example shows clearly the role of usability in relation to the learning objectives. However, in other types of simulation games this may not be such a problem for the game experience. User tests on target groups are thus essential part of game development. Previous studies show that the usability also has an impact when evaluating factors that enhance learning [41; 42]. Hence, the factors affecting the game experience, usability and UX have to be developed to serve the game as a whole.

*The findings about learning experience* were similar to the findings of previous studies about simulation games in healthcare. They reaffirmed that authenticity, interaction and feedback enhance learning [35]. An authentic situation in the game caused feeling of worry in many participants, though they described it a safe way to practice without a risk to harm the patient. This supports previous findings stating that the relaxed feeling and learning from one's own mistakes without serious consequences are experienced to enhance learning [28; 35]. According to the participants, immersion was an important part of the learning experience and it can be seen as a part of the authenticity of the game. Conversely, in previous studies immersion has not been shown to enhance learning [43; 44]. However, according to Makransky, immersion improves presence and cognitive processing [43]. In critical skills training, healthcare or otherwise, the goal may be to, for example, learn decision making under pressure, not gaining maximal amount of theoretical knowledge. Therefore, there's a potential problem in generalizing results from different fields. The contradictory results about the immersion in the previous conclusions reaffirm that the goals should determine the means of learning and scenario design [35].

A potential problem of implicating the findings of this study is that the scope is broad and it only explores the experience, not the learning outcome. However, it gives an insight to an intricate subject of the experience, which is an important aspect of the development of both health care education and serious games design. By and large, virtual gear and serious games are seen as good tools for training and an authentic virtual patient is suitable for training of clinical skills, as previous studies state [6].

Game development, on the other hand, is a complex process. Overall, this study strengthens the idea that user UX and usability play important roles in serious games and thus need to be taken into consideration from the very first steps. It is also remarkable that virtual gear brings new challenges to usability.

The quality of this study has been evaluated in terms of its trustworthiness, which includes credibility, transferability, dependability and confirmability [45]. Credibility relates to decisions about the focus of the study, the selection of the context and the participants, and the approach to collecting the data [46]. The individual gaming sessions and individual interviews were organized to encourage participants to describe personal experience as freely as possible. The group of participants was fairly small, but they represented the target audience well. Saturation was reached in some subjects already with this amount. However, this group consisted of volunteers, who replied to the group invitation. This group may have more positive attitude towards serious games than the target audience in general.

The credibility of a research can be enhanced by clearly describing the characteristics of the participants [46]. In this report, the description of the participants' profession, age, sex and previous experience of virtual reality was described. The study's credibility was enhanced by reporting the results carefully and using original quotations from the participants [45]. One must bear in mind that the original quotes have been in Finnish and were translated in English for this article. Dependability refers to the coherence of the research process and its stability over time [45]. The dependability of this study was enhanced by reporting the process of the study systematically so that the readers could follow it [46]. A limited amount of data and a low number of informants [45] may reduce the transferability of the results to other contexts. However, the results of this study share similarities with the results of previous studies, which in turn increases the transferability of this study.

Confirmability refers to the objectivity of the data [45]. In particular, due to the fact that the researcher had been involved in the scenario development and acted as a facilitator during the gaming sessions, there was a risk of influencing the thoughts and views of the participants. Objectivity was taken into account: the researcher actively aimed to be aware of her attitudes and beliefs so that they would not affect the analysis and results. The semi-structured interview was designed to be as open as possible, and not to lead the participant.

This research was established according to ethical guidelines [47; 48][47] [48]. Participants were fully informed about the purpose, content and methodology of the study before gaming sessions. In the beginning of the sessions participants received verbal and written information about the research. They were asked to sign a form confirming their permission and willingness to participate. It was clearly stated that they could withdraw from the study at any time. The information sheet explained how long the data would be kept and by whom and that it was only used for research. Informants' anonymity and confidentiality was assured during the whole research process.

## 7 Conclusion

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This study explored a new type of serious game in healthcare training and a new way of using 4D virtual simulation games. The user experiences in gaming, usability and learning were very individual and rose strong feelings. Nonetheless, every participant found 4D virtual simulation games to be a potential addition to healthcare training. In this field there are critical skills and expertise which need to be trained in authentic circumstances. Traditional manikin -based simulation training is effective, but it requires considerable resources. Manikins also lack many features that can be expressed by a virtual patient, among other things color changes of the skin, gestures, facial expressions, breathing mechanics and different environments. Yet, we only know that these authentic features added the participants' subjective experience of learning, but we lack the actual knowledge of the learning effectiveness. In this small group of volunteer participants we may see the most positive views and the findings could be very different in a group of participants, who dislike any digital game play. Nevertheless, training programs need to consider that there will always be different kinds of learners. Despite the limitations, the findings of this study

should make an important contribution to the field of healthcare training, where the need for new methods are welcomed with great interest. Future studies should aim to explore how to achieve different learning goals by means of 4D virtual simulation games compared to other methods of learning.

Healthcare training may be a field where the elements of UX, especially immersion, reached by virtual gear, can help learners to develop their decision-making skills in stressful situations and prepare them for challenging situations with real patients. The upcoming studies should measure the learning outcomes with respect to different features of UX in game scenarios to gain more accurate information about the effectiveness. One question raised by the findings is the general suitability of learning by virtual simulation. As the individual user experiences varied remarkably, a natural progression would be to analyze whom we should teach with this method. In this way, games and scenario development could be targeted to those subjects, themes and target groups, where this method is the most efficient.

In the field of acute care there are also numerous national and international guidelines, which makes it an ideal object for even bigger studies and wide use of this method. The same game scenarios can be used throughout Europe from the Mediterranean countries to the Faroe Islands. Therefore, also in terms of geographical and multidisciplinary equality, virtual simulation games could play a significant and cost-effective role in critical skills training.

Considerably more work will need to be done before 4D virtual reality simulation games can be seen as a part of the educational system. Nevertheless, the findings of this study encourage to continue research and development of this promising method.

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